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A u.h.f. vertically-polarised receiving aerial for re-broadcast links

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A UHF VERTICALLY-POLARISED RECEIVING AERIAL FOR RE-BROADCAST LINKS

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Summary

The report describes a vertically-polarised receiving aerial for use in re-broadcast links. The aerial is designed to be highly directional in the horizontal plane and to have low side and back lobes. Three versions of the aerial are required to cover the UHF television frequency bands.

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1. Introduction

UHF relay stations normally receive their programme feed by direct reception of a parent station, thereby avoiding the expense of a cable or s.h.f. link. In most cases the parent station is a main station but some relay stations will have another relay station as parent.

A horizontally-polarised 'trough' receiving aerial is used for re-broadcast link (r.b.l.) reception of main stations. This report describes the design and measured performance of a mechanically-similar type of receiving aerial to receive vertically-polarised signals from other relay stations. The aerial is arranged to be the same size as the horizontally-polarised aerial and to have the same mounting arrangements.

Co-channel interference is the main degradation at r.b.l. sites and a highly-directional horizontal radiation pattern (h.r.p.) is necessary to reduce its effect. Calculations of the levels of co-channel interference[1] assume that the h.r.p. of the r.b.l. aerial does not exceed the limits set by the templet shown in Fig. 9. This templet, which was based on an estimate of what might be achieved in practice, was therefore the target for the h.r.p.

The bandwidth must be sufficient to enable the four channels of a standard group to be received simultaneously. The horizontally-polarised aerial is made in three versions covering Band IV, Lower Band V and Upper Band V respectively and this was the target for the vertically-polarised aerial also. The largest normalised bandwidth on this basis is 1·24 : 1 in Band IV.

The impedance matching requirement is determined by the level of delayed signal which can be tolerated in the radiated signal. The delayed signal is produced by reflection of the primary signal from the imperfectly-matched transposer input and re-reflection at the aerial. The total delay is therefore equal to twice the electrical length of the feeder between the aerial and the transposer. The feeder length will not usually be more than 40 m giving a delay of 0·34 μs for which a delayed signal level of −29 dB relative to the main signal is acceptable. Assuming the reflection loss at the input to the transposer is 10 dB and assuming a feeder loss of 2·5 dB, the permissible reflection coefficient of the aerial amounts to 20%.

2. Aerial design

2.1 Design approach

To achieve high directivity in the horizontal plane the width of the aerial must be made large. The vertical dimension is of interest only in as much as it affects the aerial gain. Using dipoles spaced one quarter-wave length in front of a reflecting screen the design question is how many to choose and in what configuration to array them.

Arrays of parallel dipoles are associated with high mutual impedances so that they are less easy to match and to drive with prescribed currents. In the horizontally-polarised aerial, four collinear dipoles were required to satisfy the h.r.p. templet. Parallel dipoles need to be more closely spaced than collinear dipoles to achieve the same gain and so six elements were chosen, arranged in a single tier, side-by-side. A double tier of six, making twelve elements in all would increase the gain but the complication of driving the elements would be greater.

Full-wave dipoles were chosen for the radiating elements because their gain and impedance bandwidth are greater than those of half-wave dipoles, and they are not too large mechanically at u.h.f. Although the available bandwidth of a full-wave dipole is greater than that of a half-wave dipole, the impedance bandwidth of the whole aerial is determined by the mutual impedances between dipoles so that three versions of the aerial covering the usual standard bands are still required.

2.2 The full-wave dipole

A full-wave dipole can be considered as two half-wave dipole elements placed end-to-end and with the feed-point in the centre. The contributions to the radiation pattern from the two halves of the combined element add in phase. A full-wave dipole can be supported mechanically at the centre of each of the two half-wave sections because the resonant voltage distribution passes through an antinode at these points. However, a small current flows in the element supports because the current distribution on the dipoles is not truly sinusoidal. The effect of these currents in a metallic structure orthogonal

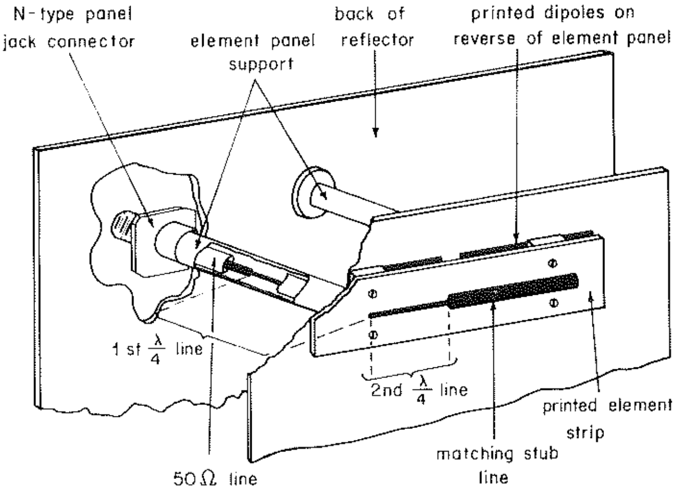

N-type panel jack connector
element panel support
back of reflector
printed dipoles on reverse of element panel
1 st $\frac{\lambda}{4}$ line
2nd $\frac{\lambda}{4}$ line
printed element strip
matching stub line
50Ω line

Fig. 1 - Detail of full-wave dipole element

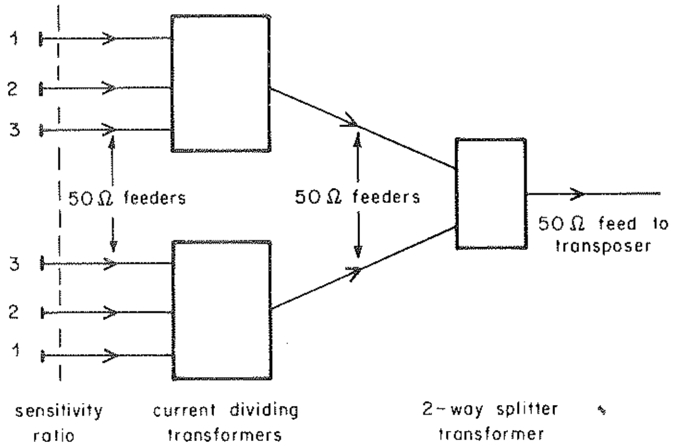


Fig. 2 - Arrangement of feed to the elements

to the radiating elements is to set up a small cross-polarised signal at large angles to the horizontal axis of the aerial, but this is substantially zero in the horizontal plane. This should not disturb the performance of the present aerial.

The driving-point impedance of a full-wave dipole is greater than that of the corresponding half-wave dipole; in the aerial under consideration it is in excess of 250 Ω. Some transformation is therefore necessary to reduce the impedance to 50 Ω.

The construction of the dipole elements is shown in Fig. 1. The dipoles are formed from copper printed on the reverse side of a laminate sheet. The feed passes up one of the supports made from brass tubing and a balun action is conveniently achieved. Two quarter-wave transformers provide the impedance transformation. The first is of coaxial form and the second is fabricated in stripline on a piece of laminate supported a small distance away from the laminate carrying the dipoles. The characteristic impedances of the transformer sections are approximately 70 Ω and 200 Ω, respectively. Reactance compensation at the drive point is achieved by an open-circuit microstrip line about a quarter-wavelength long in series with the input.

The dimensions of the radiating elements and of the microstrip line components have been chosen for the optimum impedance bandwidth over the three bands independently.

2.3 Feed to elements

The six dipoles are spaced about a half-wavelength apart in the H-plane to produce the optimum gain. They are fed in two groups of three (see Fig. 2), each group being driven from a transformer providing outputs with different current ratios. The currents fed to the dipoles are nominally in the ratios 1 : 2 : 3 : 3 : 2 : 1. These values are chosen to give low side lobes but they accentuate the matching problem owing to mutual impedances. The dipole elements are fed in phase. The two-way splitter transformer which feeds the two groups of three is described elsewhere.[2]

2.4 Current dividing transformer

The layout and construction of the current-dividing transformer is shown in Fig. 3. The transformer has a single input and three outputs providing current drives in the ratios 3 : 2 : 1. It is made up from a number of quarter-wave sections of line fabricated in microstrip form on low-loss printed-circuit board. The characteristic impedances of the sections are chosen to give both the required output current ratios into 50 Ω loads and an input impedance matched to 50 ohms.

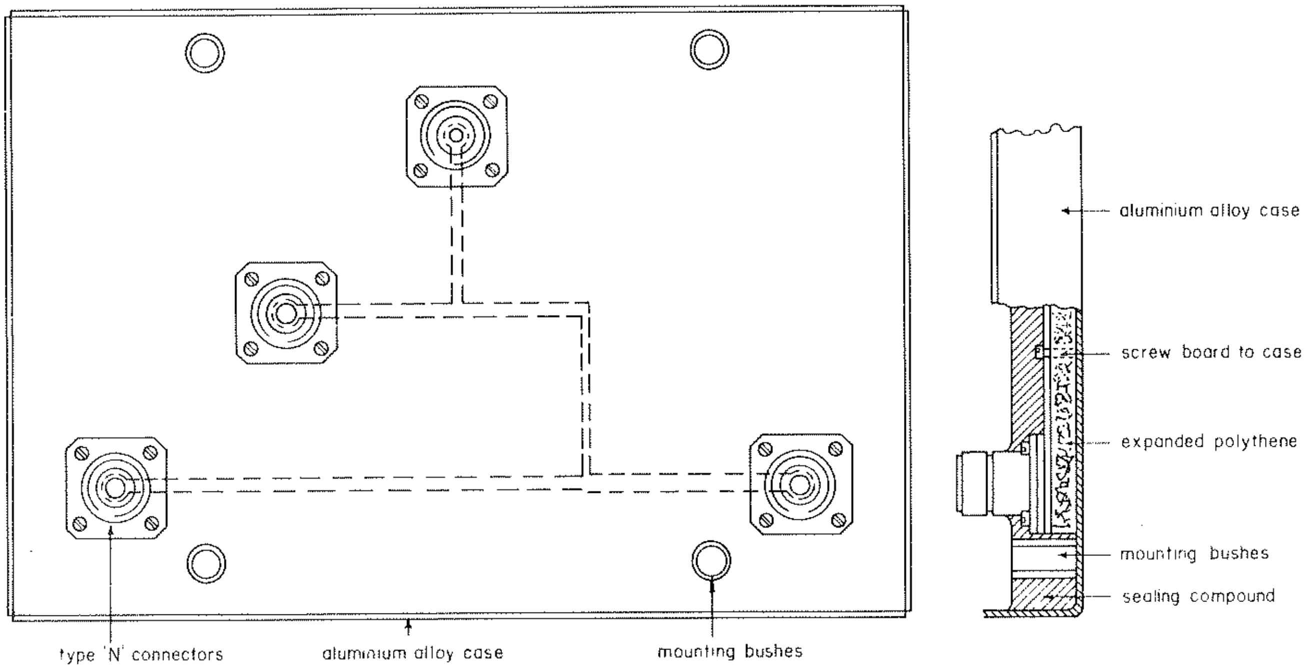


Fig. 3 - Construction of current-dividing transformer

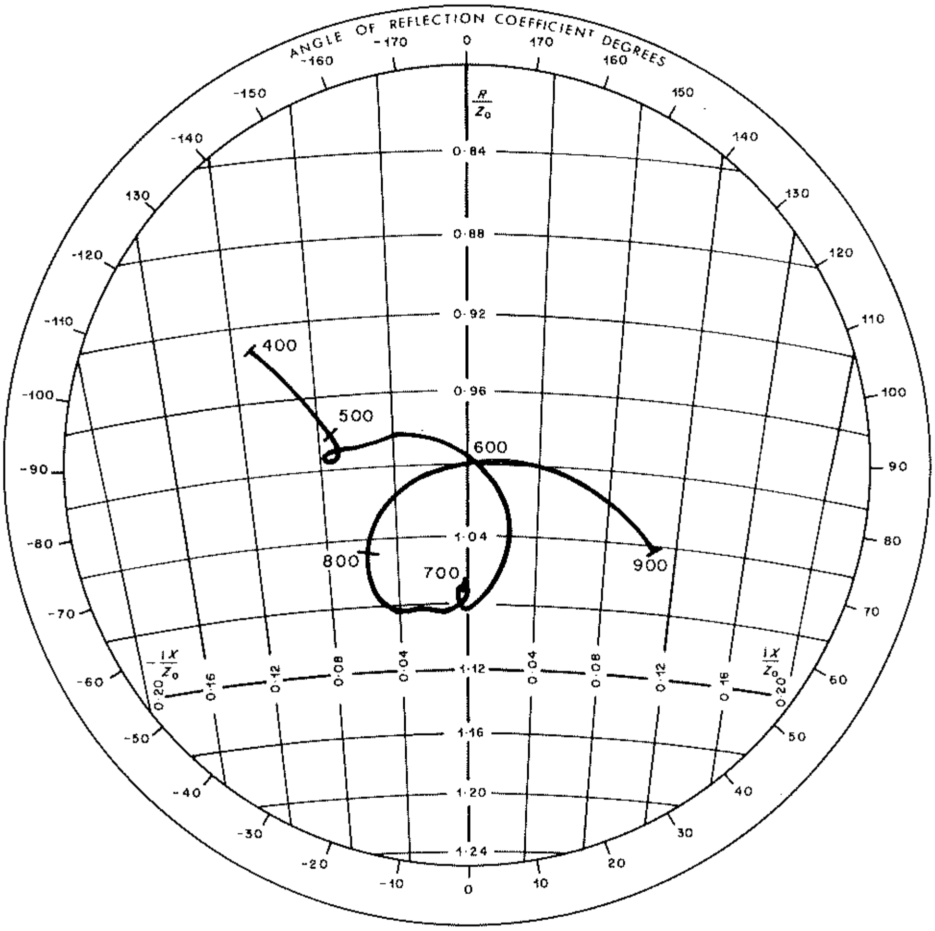


Fig. 4 - Impedance match of current-dividing transformer

The measured impedance match and output current ratios as functions of frequency are shown in Figs. 4 and 5 respectively. The outputs are nominally co-phased. The phases of the two greater outputs, A and B, deviate by less than ±5° and those of outputs A and C by less than ±15° over the frequency band 470MHz – 860MHz.

3. Mechanical construction

The vertically-polarised aerials are built in the same frames as the horizontally-polarised trough aerials. The construction is illustrated in Figs. 6 and 7. The reflector is made up from 16 swg aluminium alloy and provided with a glass-fibre cover. The dipoles are housed within the reflector shell and behind the glass-fibre cover.

The driving transformers are mounted on the back of the reflector below the horizontal centre-line. The overall dimensions of the three versions of the aerial are approximately:

	Height (m)	Width (m)	Depth (m)
Band IV	0·80	2·00	0·40
Lower Band IV	0·80	1·75	0·40
Upper Band V	0·80	1·45	0·40

4. Measured performance

4.1 Impedance match

The measured reflection coefficient and standing-wave ratio are shown in Fig. 8 for the three verisons of the aerial. In each case the reflection coefficient is less than

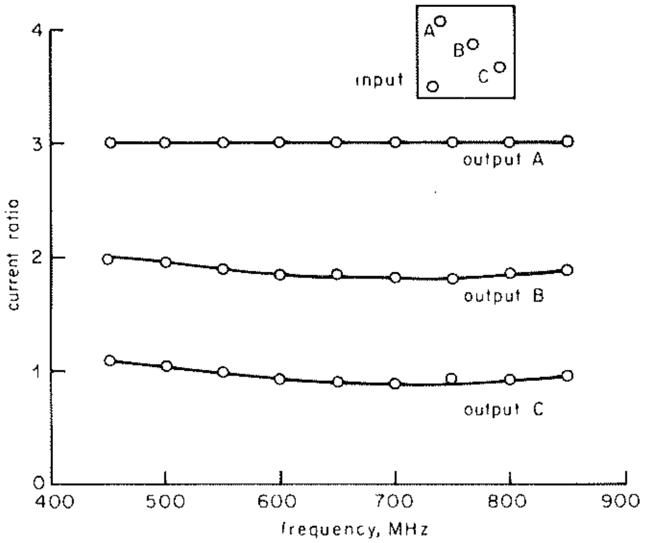


Fig. 5 - Output current ratios of current-dividing transformer

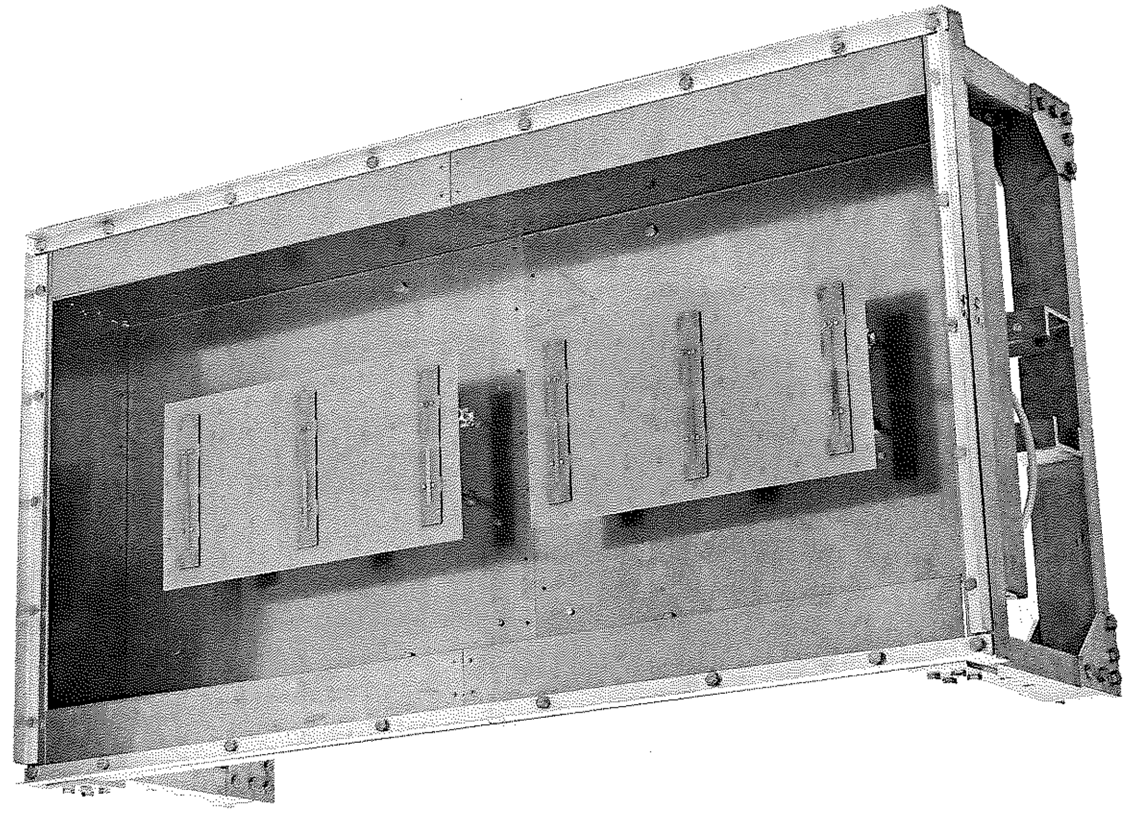


Fig. 6 - Upper Band V version of aerial: front view with glass-fibre cover removed

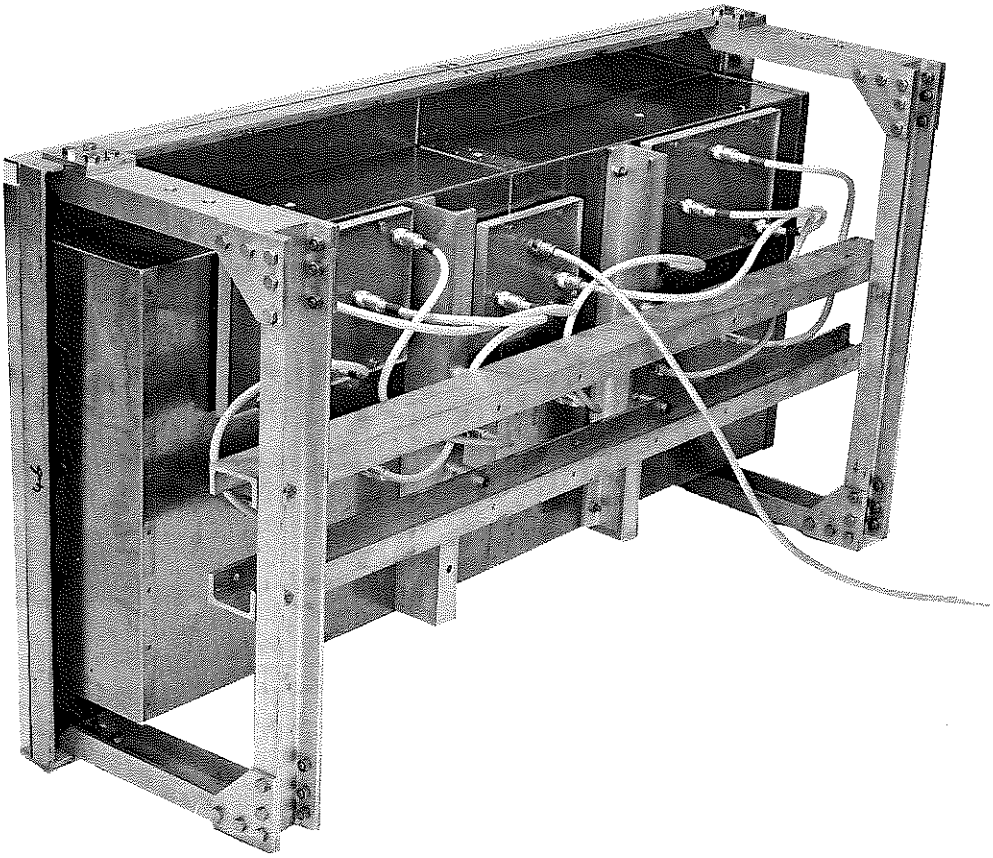


Fig. 7 - Upper Band V version of aerial: rear view (shown inverted)

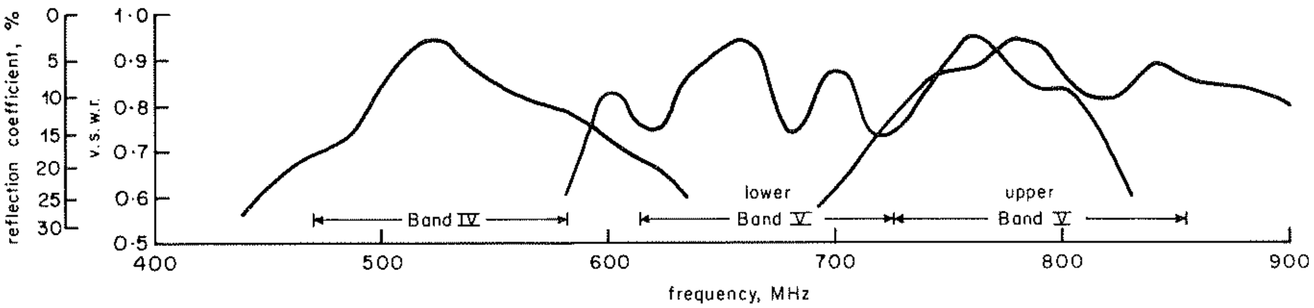


Fig. 8 - Impedance match of the three versions of the aerial

17% throughout the band to be covered. The smallest margin occurs at the low-frequency end of each band.

4.2 Radiation patterns

The horizontal radiation patterns measured at two frequencies within each band are shown in Figs. 9 to 11. In no case is there more than a minor transgression of the templet.

The corresponding vertical radiation patterns are shown, in Figs. 12 to 14 in polar form. These are broader than for the horizontally-polarised aerial.

The cross-polarised radiation is indicated in Fig. 11 for the Upper Band V version of the aerial. The CCIR recommendation on cross-polarised radiation[3] is that the level should be no greater than −20 dB on the forward-lobe radiation; this requirement is satisfied on all bearings.

4.3 Gain

The aerial gain has been computed from the measured radiation patterns. Fig. 15 shows the results expressed relative to a half-wave dipole. These gains take into account the losses associated with the transformers and interconnecting feeders.

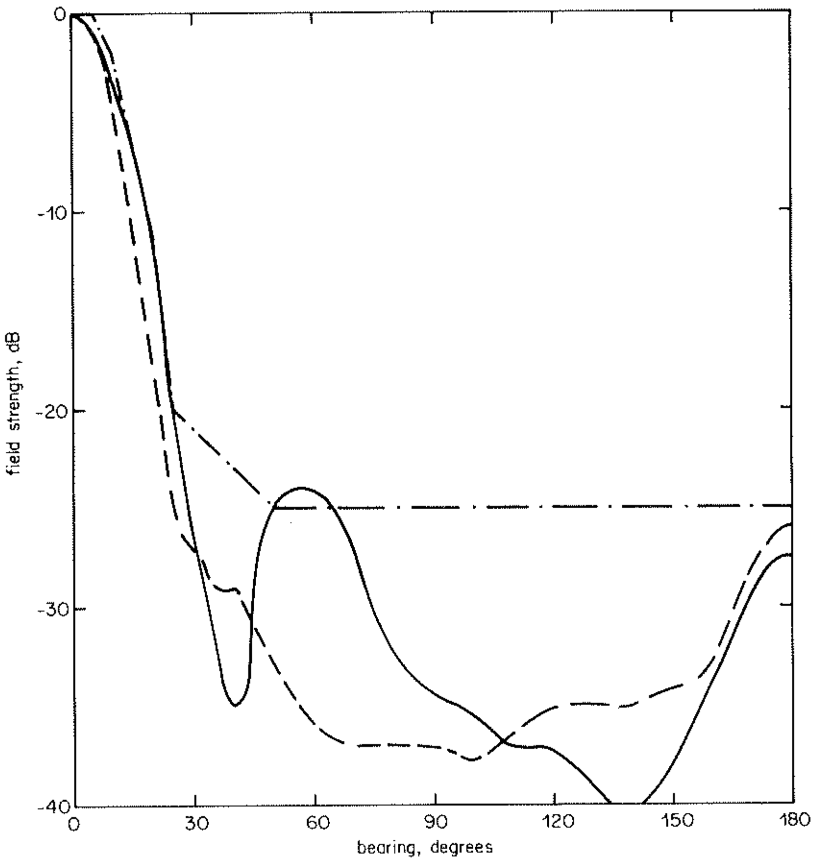


Fig. 9 - Horizontal radiation patterns of the Band IV aerial

———— 470 MHz – – – – 600 MHz —·—·— Templet

Fig. 10 - Horizontal radiation patterns of the Lower Band V aerial

———— *600 MHz* - - - - - - - *700 MHz*

-·-·-·-·- *Templet*

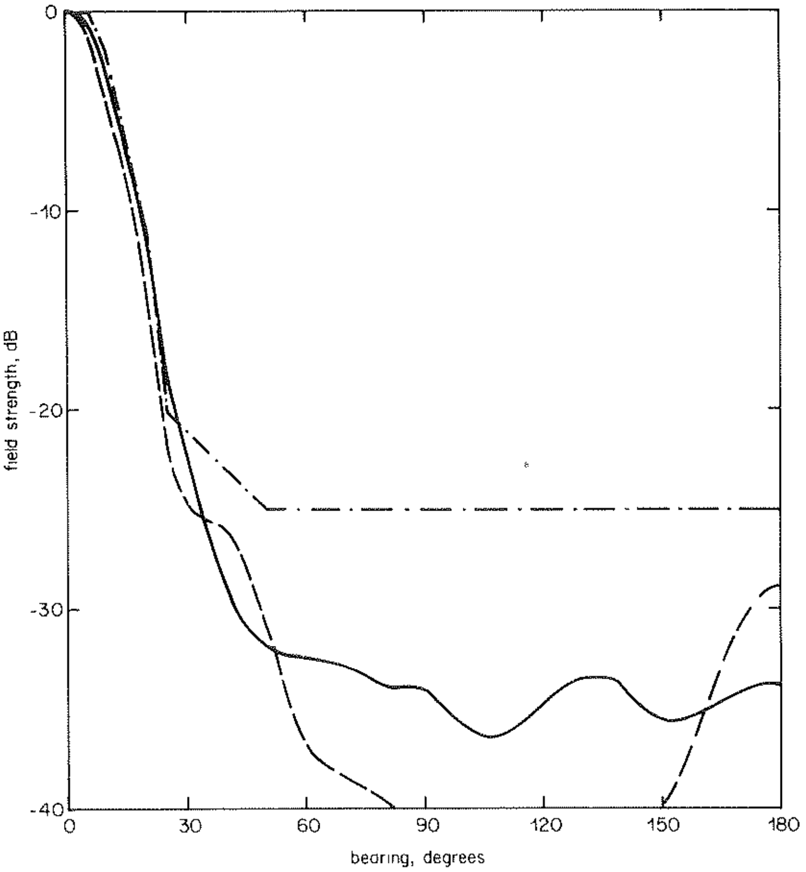
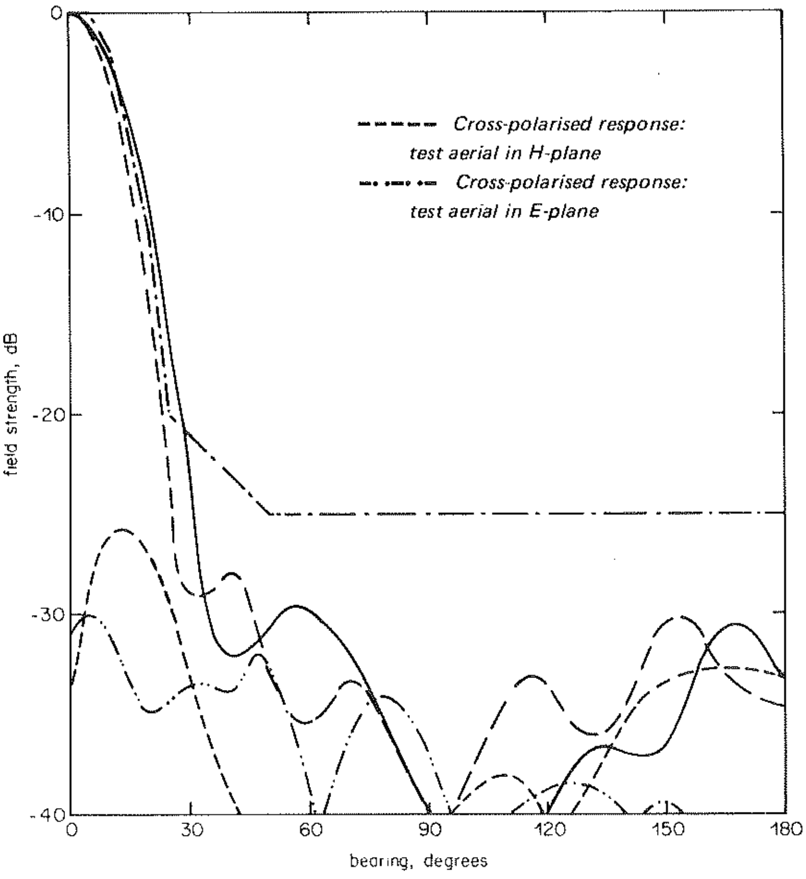


Fig. 11 - Horizontal radiation patterns and cross-polarised responses of the Upper Band V aerial

———— *700 MHz* - - - - - - - *850 MHz*

-·-·-·-·- *Templet*



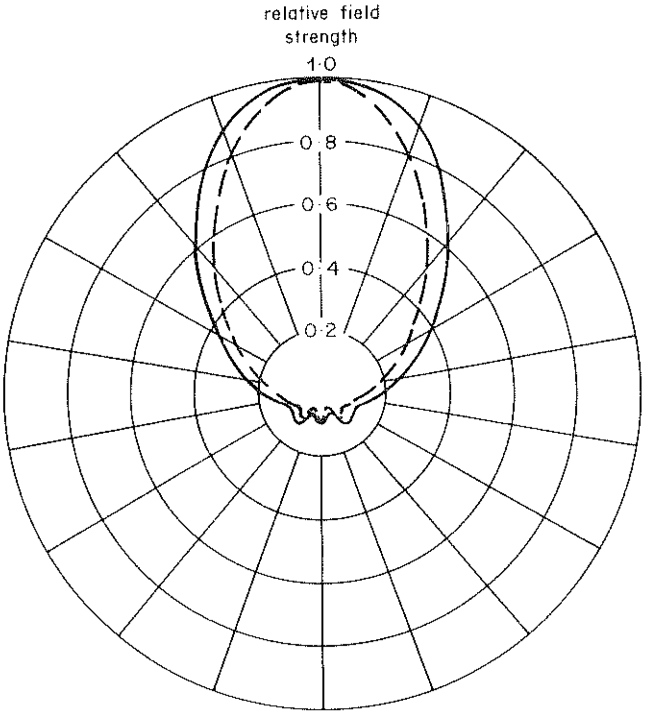


Fig. 12 - Vertical radiation patterns of the Band IV aerial
———— 470 MHz - - - - - - - - 600 MHz

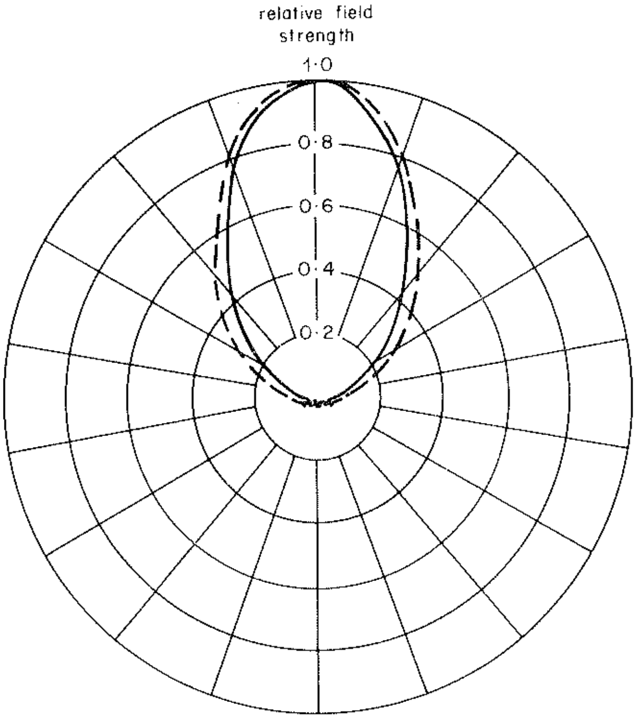


Fig. 13 - Vertical radiation patterns of the Lower Band V aerial
———— 600 MHz - - - - - - - - 700 MHz

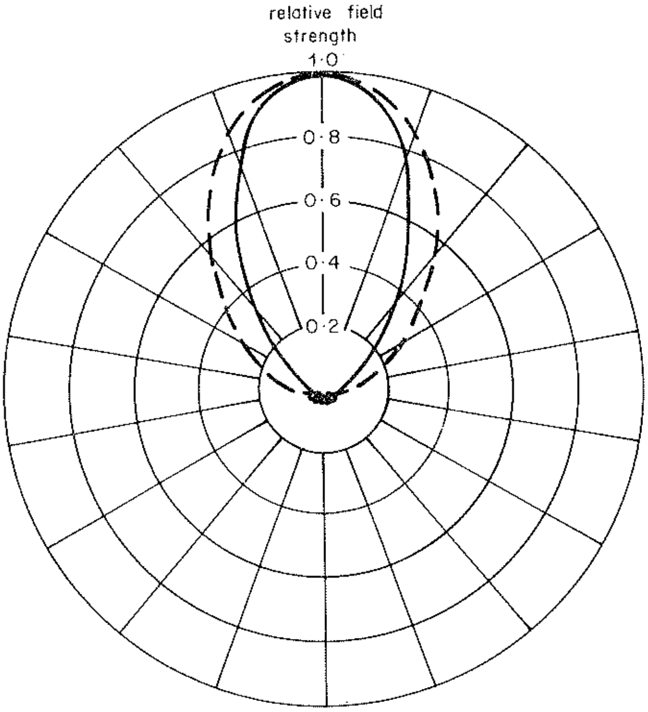


Fig. 14 - Vertical radiation patterns of the Upper Band V aerial
———— 700 MHz - - - - - - - - 850 MHz

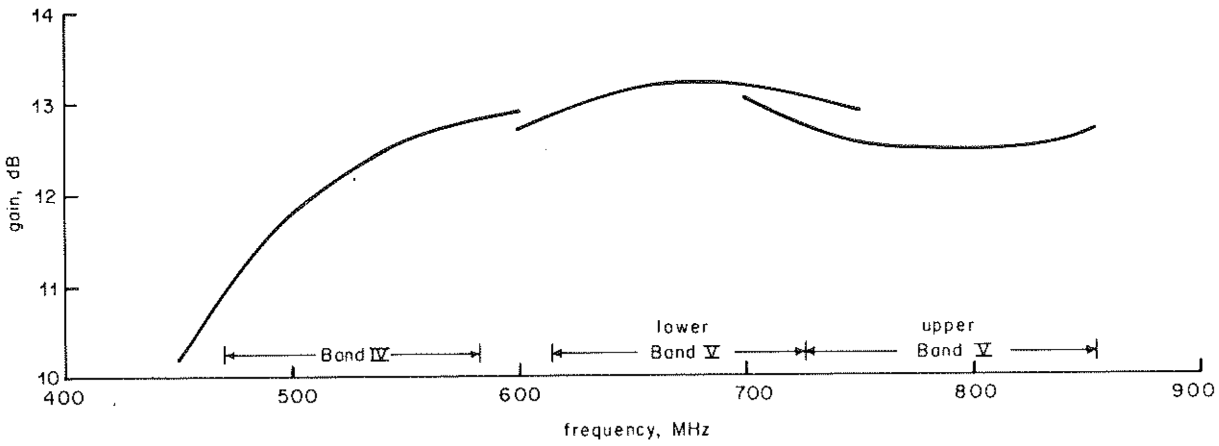


Fig. 15 - Measured gain of the thee versions of the aerial

5. Conclusions and discussion

The performance of the aerial in respect of its impedance match and horizontal radiation pattern is acceptable. The reflection coefficient measured at the input is better than 17%. The horizontal radiation pattern meets the required templet with only minor transgressions. The net aerial gain is lower than that of the horizontally-polarised aerial, especially at the lower end of Band IV. This results from the difficulty of utilising the vertical dimension as effectively as in the horizontally-polarised aerial without a further increase in the number of driven elements and consequent feeding complexities.

6. References

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